

SECTION 23 31 14

DUCTWORK FOR TUNNEL VENTILATION

PART 1 – GENERAL

1.01 SECTION INCLUDES

- A. The work of this Contract Specifications Section includes furnishing, installing, and testing of Ventilation System Accessories as shown on the Contract Drawings, including the ductwork, flexible connections, screens, and all structural support elements and hardware for the installation of equipment.

1.02 RELATED SECTIONS

- A. Section 23 33 14, Dampers for Tunnel Ventilation
- B. Section 23 33 20, Sound Attenuators for Tunnel Ventilation
- C. Section 23 34 14, Fan Motor Units for Tunnel Ventilation

1.03 MEASUREMENT AND PAYMENT

- A. General: Separate measurement or payment will not be made for the work required under this Section. All costs in connection with the Work specified herein will be considered to be included or incidental to the Work of this Contract.

1.04 REFERENCES

- A. Where materials or equipment are required to conform to referenced industry standards, the current edition of the most recent revisions as of the date of Notice to Proceed shall apply.
- B. Contractor may propose for approval alternate standards to those listed herein, provided that the standards are submitted in the English language, with a point-by-point comparison between the specified and alternate standards included in the submittal. The requirements of proposed alternate standards shall be at least as stringent as the specified standards.
- C. Reference Standards:
 - 1. American Iron and Steel Institute (AISI)
 - a. Type 316, Stainless Steel.
 - 2. American National Standards Institute (ANSI):
 - a. C1, General Requirements of a Quality Program.
 - 3. ASTM International (ASTM):

- a. A 36, Carbon Structural Steel.
 - b. A 123, Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
 - c. A 193, Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.
 - d. A 194, Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service.
 - e. A 239, Locating the Thinnest Spot in Zinc (Galvanized) Coating on Iron or Steel Articles.
 - f. A 276, Stainless Steel Bars and Shapes.
 - g. A 666, Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate and Flat Bar for Structural Applications.
 - h. A 780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
4. American Welding Society (AWS):
- a. AWS B5.1, Specification for the Qualification of Welding Inspectors.
 - b. D1.1, Structural Welding Code - Steel.
 - c. D1.3, Structural Welding Code - Sheet Steel.
 - d. D19.0, Welding Zinc-Coated Steels.
 - e. QC1, Standard for AWS Certification of Welding Inspectors.
5. National Fire Protection Association (NFPA):
- a. 90A, Installation of Air Conditioning and Ventilating Systems.
 - b. 130, Standard for Fixed Guideway Transit and Passenger Rail Systems
6. Sheet Metal and Air Conditioning Contractor's National Association Inc. (SMACNA):
- a. Rectangular Industrial Duct Construction Standards, I-P Second Edition.
 - b. Round Industrial Duct Construction Standards
7. Steel Structures Painting Council (SSPC):
- a. PA-1, No. 1 Shop, Field and Maintenance Painting.
8. Underwriter's Laboratories, Inc. (UL)

1.05 SYSTEM DESCRIPTION

- A. Design Temperature Conditions: Ductwork and accessories shall be selected and designed to permit continuous operation at an ambient temperature of not less than 482 degrees Fahrenheit.

- B. Design Pressure Conditions: Ductwork and accessories shall be capable of withstanding the stresses caused by pressure transients from train piston action, and by reversal of airflow. The ductwork and accessories shall withstand a differential pressure of 14 inches water gauge from atmospheric conditions, or fan shut-off pressure (resulting from possible operation of the ventilation fan against a closed damper), whichever is higher. Coordinate with fan manufacturer to establish maximum fan shut-off pressure.
- C. Critical Load Conditions: The design of ductwork, attenuator exterior casings, and fan-to-duct transitions shall account for the largest total load that the ductwork, attenuator exterior casings and transitions will be subjected to under the various operating conditions described in Article 2.02 herein.

1.06 SUBMITTALS

- A. Provide submittals in accordance with Contract Specifications Section 01 33 00, Submittal Procedures, Contract Specifications Section 01 33 23, Shop Drawings, Product Data, and Samples, Contract Specifications Section 01 42 19, Reference Standards, and the requirements herein. In case of conflict, the more stringent requirement shall take precedence.
- B. The Contractor shall submit the following:
 - 1. Certified Shop Drawings, including Bill of Materials, for fan ductwork, flexible connections, and screens; installation drawings, installation instructions; dimensioned drawings for installation of structural steel members (columns, mullions, lintels, and other structural support members) to be furnished by manufacturer; weight of components and additional components and data required for proper installation.
 - 2. Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein.
 - 3. List of technical support items specified and list of additional support items required.

1.07 QUALITY CONTROL

- A. Welding: All Components in this Contract requiring welding shall be welded as follows:
 - 1. Code Requirement: Welding shall conform to the requirements of AWS D1.1 and AWS D1.3.
 - 2. Welder Qualification: Welders welding on the work of this Contract shall be qualified in accordance with the requirements of AWS D1.1.
 - 3. Welding Inspections:

- a. Visual Inspection: All welds shall be visually examined in accordance with AWS D1.1, Section 6 and 7.8, as applicable. Quality of welds and standards of acceptance shall be in accordance with AWS D1.1, Sections 8.15.1, 9.25.1, and 10.17.1, as applicable.
- b. All shop and field welding for Station ventilation fan system ductwork shall be visually inspected and approved by an independent inspection or testing laboratory, or technical consultant. The inspector shall be an independent Certified Welding Inspector (CWI) who has met the qualification and program requirements of the American Welding Society (AWS) to certify welding inspectors, as specified in AWS QC1 and the requirements of 5.2, 6.1, and 6.2 of AWS B5.1.
- c. The CWI shall file an inspection results report with the District Representative.
- d. The welding shall be subject to inspection and tests in the shop and in the field. Inspections shall be made prior to galvanizing, painting, or otherwise finishing of the welded materials. Inspection in the shop will not relieve the Contractor of the responsibility to furnish welds of satisfactory quality.
- e. When inspection indicates defects in the weld joints, the welds shall be repaired using a qualified welder or welding operator as applicable. Corrections shall be made in accordance with the requirements of AWS D1.1/D1.1M. Corrections and repairs shall be made at no additional cost to the District Representative or its agents.
- f. All welds are subject to inspections and tests by the District Representative. Welds to be inspected and tested by the District Representative will be selected at random.

1.08 STORAGE AND PROTECTION

- A. Storage: Store all materials and equipment in dry, ventilated, weather tight enclosures.
- B. Protecting Machined Surfaces: Apply a rust preventive on machined surfaces such as flanges and shafts. Use material of a type that is easily removable with solvent during equipment installation.
- C. Protecting Openings: Close pipe connections, ends, and other openings with easily removable plugs, stoppers, or flange covers.

1.09 CONTRACT/JOBSITE CONDITION

- A. Surfaces and structures to which the products will be affixed, placed, and installed shall be inspected by Contractor in the presence of the equipment manufacturer and the District Representative before the work begins. Surfaces that will be concealed by products shall be finished before products are installed.

PART 2 – PRODUCTS

2.01 DUCTWORK, CASINGS AND TRANSITIONS

A. General

1. Ductwork and attenuator exterior casings, fan-to-duct transitions and all parts thereof shall be capable of withstanding the thermal expansion and operational stresses under Design Temperature Conditions.
2. Ductwork and attenuator exterior casings shall be fabricated of hot-rolled steel in conformance with the requirements of ASTM A-36 with minimum thickness in accordance with the requirements of SMACNA Rectangular or Round Industrial Duct Construction Standards Section 6.6.1 Duct Selection Tables and shall have companion flanges at both ends. Fan-to-duct transitions shall be fabricated of hot-rolled steel not less than the gauge of the connecting ductwork or attenuator casings and shall have companion flanges at both ends. Ductwork, attenuator exterior casings and fan-to-duct transitions shall be hot-dip galvanized after companion flanges and all additional reinforcement and stiffeners have been welded in place.
3. Ductwork, attenuator exterior casings, and fan-to-duct transitions shall be designed in accordance with SMACNA Rectangular or Round Industrial Duct Construction Standards, and shall be capable of withstanding the critical load for each ventilation fan system without deformation, excessive deflection, or panel vibrations in excess of 50 percent of panel metal thickness. The critical load shall be the largest total load that the ductwork will be subjected to under the various operating conditions described in Article 2.02 herein. In accordance with the SMACNA definitions Stiffeners and Supports are different. Stiffeners act as beams and Supports act as columns. The use of internal bracing is not allowed. Neither Supports nor Stiffeners shall be utilized inside of the ductwork, attenuator exterior casing, fan-to-duct transitions or other parts of the duct system.
4. Ductwork, attenuator exterior casings and fan-to-duct transitions shall be fabricated in multiple sections.
5. All transverse joints used for the connection of ductwork and attenuator exterior casings and fan-to-duct transition sections shall be flanged, gasketed, and bolted together to form an airtight perimeter. Flanges shall be fabricated of galvanized steel structural channels in conformance with ASTM A-36 and sized in accordance with the requirements of SMACNA Rectangular Industrial Duct Construction Standards Section 6.7 Auxiliary Tables 6-B2 through 6-B20, but no less than the minimum flange height specified in Table 6-G1. Transverse joints shall be SMACNA Standard Figure 11-3, type E, with the exception that a continuous weld shall be used in every location in the SMACNA figure that indicates use of a stitch weld.
6. The minimum size of bolts to be used for the connection of ductwork and attenuator exterior casing and fan-to-duct transition sections shall be in accordance with the requirements of SMACNA Rectangular Industrial Duct Construction Standards Table 6-G1.

7. The maximum bolt pitch, or spacing between the bolts, to be used for the connection of ductwork and attenuator exterior casing and fan-to-duct transition sections shall be in accordance with the requirements of SMACNA Rectangular Industrial Duct Construction Standards Table 6-G1. Bolt holes shall be equally spaced and symmetrical across the length of each companion flange. The maximum distance from each end of the companion flange to each end bolt hole shall be one-half of the actual bolt hole pitch.
8. The maximum bolt hole gauge, or distance from the surface of the duct, attenuator casing panel, or fan-to-duct transition section surface to the centerline of the bolt hole in the companion flange, shall be as in accordance with the requirements of the SMACNA Rectangular Industrial Duct Construction Standards Table 6-G2.
9. All ductwork and attenuator exterior casing panel longitudinal seams (those seams connecting the top end side panels or sheets to each other) shall be of the continuous welded type only. Longitudinal seams shall be one of the following types: SMACNA Standard Figure 11-1, type A, B, C, D, E, F, and Figure 11-2, type G, H, I, and including the welded seam that is labeled type J, with the exception that a continuous weld shall be used in every location in the SMACNA figures that indicates use of a stitch weld.
10. Non-welded longitudinal seams of any type shall not be permitted for ductwork and attenuator exterior casings. SMACNA standard Figure 11-2, type K, L, and the grooved seam pipe lock also tagged as type J shall be specifically excluded from use on this Contract.
11. Flanged, gasketed, and bolted longitudinal seams (those seams aligned with the airflow direction) shall be permitted for fan-to-duct transitions, and shall be constructed as shown in SMACNA Standard Figure 11-3, Type E, with the exception that a continuous weld shall be used in every location in the SMACNA figure that indicates use of a stitch weld.
12. Covering or obscuring of welded ductwork seams with any miscellaneous materials which are not part of the ductwork construction, as indicated in the SMACNA standards shall not be permitted. Any such materials that are installed shall be removed and the ductwork surfaces repaired.
13. Each ductwork and attenuator exterior casing section shall be match-marked with stencils in a conspicuous location for identification at the Jobsite. The sections shall be of such size that can be brought into the fan rooms or to their installation locations through the access provided and to facilitate handling, erection, and disassembly.
14. Ductwork and attenuator exterior casings shall be reinforced with exterior mounted stiffeners designed in accordance with SMACNA Rectangular Industrial Duct Construction Standards Section 6.7 Auxiliary Tables 6-B2 through 6-B20, and shall be capable of withstanding the critical load for each emergency ventilation system without deformation or excessive deflection and to limit ductwork panel vibration to not more than 60 percent of ductwork panel metal thickness during fan-motor unit operation. The critical load shall be the largest

total load that the ductwork will be subjected to under the various operating conditions described in Article 2.02B herein.

15. Steel for ductwork, attenuator exterior casing, and fan-to-duct transition reinforcement stiffeners and the companion flanges shall be single lengths of structural bar, angle, channel, or beam sections, conforming to the requirements of ASTM A-36. The companion flanges shall also act as stiffeners, and shall be designed to meet the same critical loads as the stiffeners. Companion flanges and stiffeners shall be continuous and shall extend around the entire exterior perimeter of the ductwork and the attenuator casings. Companion flanges for rectangular ducts shall be structural steel conforming with the requirements of ASTM A-36. Companion flanges shall be sized to match the flanges of the duct, flexible connection, or fan casing which is being connected. Contractor shall coordinate all of the companion flange sizes for all system components. Stiffeners or supports mounted inside of the ductwork are not acceptable. Stiffeners and companion flanges spliced together from shorter lengths of the required structural sections shall not be permitted. Stiffeners and companion flanges shall be protected by an additional coating of zinc-rich paint after installation.
16. Terminating ends of reinforcing stiffeners shall be rounded or beveled.
17. The steel sheets that will form the ductwork, attenuator exterior casing, fan-to-duct transition sections and the structural steel sections to be used as companion flanges shall be cut to the required sizes, the holes for the connecting bolts shall be punched or drilled into the companion flanges, and the companion flanges welded to the ends of each duct and casing panel prior to hot-dip galvanizing the assembled panel.
18. Contractor shall comply with the requirements of AWS D19.0 calling for welds to be made on surfaces free of lead and zinc, and shall coordinate with the hot-dip galvanizing vendor to mask those portions of the duct and casing panels that shall be subjected to further welding operations during assembly of the ductwork and attenuator casings. This includes, but is not limited to, the locations of the intermediate stiffeners, hanger frames, and the edges of the panels to be welded to form the longitudinal seams. Contractor shall restore the protective coating of all system components when welding and assembly are completed, in compliance with the requirements of ASTM A 780-01, to build a zinc-rich film to the thickness required by the standard.
19. Access doors shall be the flanged frame type, constructed in accordance with the SMACNA standard, Figure 11-11. Each door opening shall be framed with structural steel sections continuously welded to the duct surface. Access doors shall be double panel doors with the outer panel forming an air-tight seal with the frame, and the inner panel shall be flush with surface of the duct to reduce air pressure losses and turbulence. Access doors shall be of the same material as ductwork and shall be provided where indicated. Each access door shall have a clear opening size not less than 36 inches high by 30 inches wide. Access doors shall be provided with not less than 1/4 inch thick silicone gaskets to ensure airtight construction. Access doors shall be provided with wedge type latches,

and welded Type 316 stainless steel flat bar hinges. Handhold bar shall be provided above top of access door.

20. Contractor shall provide a 1/4 inch thick silicone gasket between all adjacent companion flanges; width of gaskets shall be same as flange width. Gaskets shall be capable of withstanding Design Temperature Conditions without emitting toxic or noxious fumes.
21. Transitions shall be designed in accordance with AMCA 210 Except as noted. The shape of the transition elements shall be limited to 15 degrees converging and diverging.

2.02 CRITICAL LOADS

- A. The critical load used for designing the ductwork and attenuator exterior casings, and fan-to-duct transitions shall be the greatest of the loads following operating conditions:
 1. Fan shut-off condition: Fan(s) on; system air pressure equal to the fan shutoff pressure (resulting from possible operation of the ventilation fan against a closed damper); normal ambient temperatures, less than 120 degrees Fahrenheit; no maintenance load.
 2. Emergency operation condition: Fan(s) on; fan total pressure equal to the values indicated in the Ventilation Fan Schedule, operating at 482 degrees Fahrenheit; no maintenance load.
 3. Maintenance operation condition: Fan(s) off; system air pressure equal ambient pressure; normal ambient temperatures less than 120 degrees Fahrenheit; maintenance load applied to horizontal surfaces as described below.
- B. Critical Load Calculation Components
 1. Operating pressure: Operating pressure shall be defined as 5.1 inches water gauge differential pressure. For purposes of these calculations, operating pressure shall be applied as a positive pressure to the lower duct and attenuator panels and a negative pressure to the upper panels for horizontal fan and duct orientation. Both positive and negative operating pressure shall be considered for calculation of critical loads for side panels for vertical fan and duct orientation.
 2. Train passage pressure: Train passage pressure, resulting from pressure transients generated by passage of trains, shall be defined as a minimum cycling value of plus or minus 14.0 inches water gauge differential pressure. For purposes of these calculations, operating pressure shall be applied as a positive pressure to the lower duct and attenuator panels and a negative pressure to the upper panels for horizontal fan and duct orientation. Both positive and negative operating pressure shall be considered for calculation of critical loads for side panels for vertical fan and duct orientation.
 3. Shut-off pressure: Shut-off pressure, resulting from possible operation of the Station ventilation fan(s) against a closed damper(s), shall be defined as the

greater of either the actual shutoff pressure of the fans to be provided by the contractor for each emergency ventilation system, or a minimum value of 14.0 inches water gauge differential pressure. For purposes of these calculations, operating pressure shall be applied as a positive pressure to the lower duct and attenuator panels and a negative pressure to the upper panels for horizontal fan and duct orientation. Both positive and negative operating pressure shall be considered for calculation of critical loads for side panels for vertical fan and duct orientation.

4. Temperature: See Article 2.02A herein.
 5. Duct and attenuator casing panel loads: the dead weight of each sheet metal panel shall be included in the calculations as required by the SMACNA Standard.
 6. Stiffener and connection flange loads: the dead weight of the stiffeners and connection flanges shall be included in the calculations as required by the SMACNA Standard.
 7. Maintenance loads: An allowance for the weight of an installer or a maintenance worker to be on top of or within an emergency ventilation system duct or attenuator casing for horizontal fan and duct orientation shall be included in the critical load calculations as required by the operating conditions described in Article 2.02B herein. The maintenance load is dependent on the assumed weight of the person and tools, and upon the stiffener spacing used for the affected emergency ventilation system component. Calculation of maintenance loads shall be in accordance with SMACNA Rectangular Industrial Duct Construction Standards Section 4.4.2.5.
- C. Seismic Criteria: Equipment furnished for this work shall be capable of withstanding the seismic loading in accordance with BART Facilities Standards, Criteria, Structural-Seismic Design, without adverse effect on performance, operation, or life expectancy.

2.03 FLEXIBLE CONNECTIONS

- A. Flexible connections shall be as indicated on the Contract Drawings and consist of fabric connector material and fabric securing bars. Flexible connections shall be fabricated from material capable of operating at Design Temperature Conditions without failure.
- B. Flexible connections shall be designed to allow sufficient radial, axial, rotational, and lateral movement of Station ventilation fan-motor unit assembly resulting from expansion, contraction, and dynamics of air moving unit operations, without unnecessary slack in fabric connector material.
- C. Flexible connections and all components thereof shall be designed to be airtight and provided in accordance with the code requirements of the applicable NFPA 90A.
- D. Flexible material shall have a nominal thickness of not less than 1/8-inch; it shall be flame-resistant, abrasion-resistant, and able to withstand, without deleterious effect, saturation with grease and oil. The corners on rectangular flexible connections shall

be completely molded and free of splices. The total length of the flexible connection shall be a minimum of 12 inches.

- E. Companion flange angles shall be fabricated of Type 316 stainless steel, in accordance with the requirements of ASTM A 276. Companion flanges shall be sized to match the flanges of the duct or equipment which is being connected. Contractor shall coordinate all of the companion flange sizes for all system components.
- F. Companion flange angles shall have punched or drilled holes sized to receive the size bolts required by the equipment being connected. The hole pitch, or spacing between the bolts, locations, and the bolt hole gauge, or distance from the duct or casing panel surface to the centerline of the bolt hole in the companion flange, shall match that of the connecting equipment. The companion flanges shall be an integral part of the flexible connection. Contractor shall coordinate all of the companion flange bolt patterns for all system components.
- G. The fabric securing bar shall be a minimum of 3/8 inch thick by two inches wide and fabricated from Type 316 stainless steel, chambered or rounded edge bar stock conforming to ASTM A 276 and A 666.
- H. Flexible connection flow liner shall be fabricated of Type 316 stainless steel, minimum No. 10 U.S.S. -gauge thickness, in accordance with the requirements of ASTM A 666.
- I. Flexible connections shall not be painted or used to correct misalignment.
- J. Flexible connections shall be designed in accordance with SMACNA Industrial Duct Construction Standard and shall be capable of withstanding the critical load for each emergency ventilation system. The critical load shall be the largest total load that the ductwork will be subjected to under the various operating conditions described in Article 2.02 herein.

2.04 GUARD SCREENS

- A. Unless otherwise specified herein or indicated on the Contact Drawings, guard screens shall be one half inch by one half inch wire mesh fabricated of No. 18 U.S.S. gauge steel wire. The screen shall be reinforced across the shorter dimension with one and one half inch by one and one half inch by No. 10 USS gauge steel angles at midpoint. Guard screen shall be provided with rigid flanges not less than one inch wide fabricated of not less than No. 16 U.S.S. gauge steel, designed for bolting to mating companion flanges. Guard screen, frames and reinforcing angles shall be Type 316 stainless steel in accordance with the requirements of ASTM A 276.
- B. Screen frames shall be bolted to companion flanges with bolts spaced not more than 12 inches on center.

2.05 INSTALLATION HARDWARE

A. Fasteners:

1. In accessible areas, fasteners shall be hexagonal head bolts with hexagonal head nuts, washers and heavy-duty lock washers.
2. In inaccessible areas, fasteners shall be hexagonal head tap bolts with suitable flat washers and heavy-duty lock washers.
3. Bolts shall not be less than one half inch in diameter unless otherwise indicated.
4. Hardware shall be stainless steel bolts, nuts, and flat washers. Bolts and tap bolts shall conform to the requirements of ASTM A 193, Grade B8M or B8MA, equivalent to AISI Type 316, with suitable lock washers in accordance with ANSI B18.21.1. Nuts shall be stainless steel and shall conform to the requirements of ASTM A 194, Grade 2H, equivalent to AISI Type 316.

B. Expansion Bolts:

1. Expansion bolts shall be Type 316 stainless steel double element type of not less than 3/4 inch in diameter, with suitable Type 316 stainless steel flat and heavy-duty lock washers.
2. Expansion bolts shall be submitted for approval.

C. Apply coat of dielectric separator, Tnemec 10-99 or approved equivalent, to galvanized steel surfaces in contact with stainless steel hardware and expansion bolts, or use plastic insulators with shoulders to prevent direct contact of stainless steel hardware and expansion bolts with galvanized surfaces.

2.06 SHOP FINISHES

- A. All galvanized parts shall have either a hot-dipped or an electro-deposited zinc coating. The weight of the coating shall not be less than two and one half ounces per square foot of surface. The zinc coating shall be applied after the material is fabricated. Galvanized steel angles used for companion flanges, structural support elements, or legs for ductwork and attenuators shall be protected by an additional coating of zinc-rich paint after installation. The galvanizing shall conform to ASTM A 123; and withstand an eight-dip Preece Test in accordance with ASTM A 239.
- B. All steel components provided with a hot-dipped galvanized coating shall be sufficiently braced during the galvanizing process to prevent buckling or warping of surfaces.
- C. Zinc-rich topcoat paint material shall be applied to galvanized structural steel ductwork and accessories angles in accordance with the paint manufacturer's printed paint application instructions and in accordance with the applicable non-conflicting requirements of SSPC PA-1.

PART 3 – EXECUTION

3.01 INSTALLATION

- A. Products shall be installed, aligned, connected, and tested in accordance with approved Shop Drawings, and in accordance with the respective equipment manufacturer's printed installation instructions and under supervision of equipment manufacturer's field service engineer.
- B. Contractor shall furnish hardware to companion flange attachment for companion flanges. Hardware shall be as specified herein above.
- C. Apply anti-seizing compound to the threads of stainless steel bolts and studs.
- D. Use torque wrenches to obtain required bolt tension without applying excessive torque.
- E. Galvanized surfaces damaged during shipment, welding or installation and any areas of steel surfaces remaining uncoated after hot-dip galvanizing shall be repaired in accordance with the requirements of ASTM A 780, Standard, to build a zinc-rich film to the thickness required by the standard.

END OF SECTION 23 31 14